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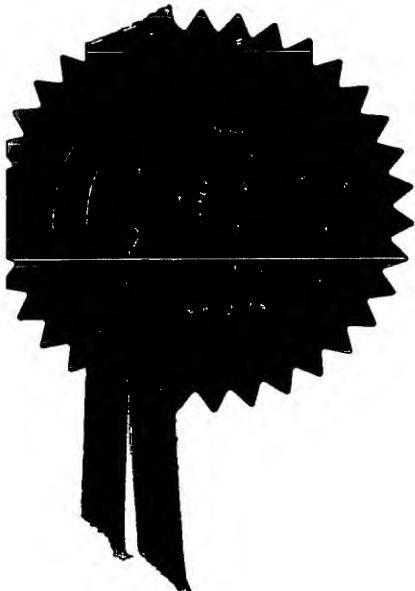
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Request for grant of a

Patent

Form 1/77

5 AUG 1998

Patents Act 1977

① Title of invention

I Please give the title of the invention

Novel Device

② Applicant's details

First or only applicant

2a If you are applying as a corporate body please give company name:

SmithKline Beecham GmbH & Co. KG.

5111073502

Country (and State of incorporation, if appropriate) Germany

2b If you are applying as an individual or one of a partnership please give in full:

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Forenames

2c In all cases, please give the following details:

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(if applicable)

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ADP Number 571711001

2d, 2e and 2f: If there are further applicants please provide details on a separate sheet of paper



Second applicant (if any)

If you are applying as a corporate body please give:
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(*if applicable*)

Country

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(3) Address for service details

3a Have you appointed an agent to deal with your application?

Yes

No go to 3b



please give details below

Agent's name

R F Walker

Agent's address

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Corporate Intellectual Property

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Agent's ADP number

1374602003

3b: If you have appointed an agent, all correspondence concerning your application will be sent to the agent's United Kingdom address.

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④ Reference number RFW/EB/C70361

4. Agent's or
applicant's reference
number (if applicable)

⑤ Claiming an earlier application date

5. Are you claiming that this application be treated as having been filed on the date of filing of an earlier application?

Yes No  go to 6



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application or patent
number

filing date (day month year)

and the Section of the Patents Act 1977 under which you are claiming:

15(4) (Divisional) 8(3) 12(6) 37(4)

⑥ Declaration of priority

6. If you are declaring priority from previous application(s), please give:

Country of Filing	Priority application number (if known)	Filing Date (day, month, year)

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7

⑦ Inventorship

- any applicant is not an inventor
- there is an inventor who is not
- an applicant, or
- any applicant is a corporate body.

⑧ Please supply duplicates of claim(s), abstract, description and drawings).

7. Are you (the applicant or applicants) the sole inventor or the joint inventors? Please mark correct box

Yes

No

A Statement of Inventorship on Patents Form 7/77 will need to be filed (see Rule 151.).

⑨ Checklist

8a Please fill in the number of sheets for each of the following types of document contained in this application

Continuation sheets for this Patents Form 1/77

Claim(s)	3	<i>R</i>	Description	15
Abstract	-	<i>R</i>	Drawing(s)	11

8b Which of the following documents also accompanies the application?

Priority documents (please state how many)

Translation(s) of Priority documents (please state how many)

Patents Form 7/77 - Statement of Inventorship and Right to Grant

Patents Form 9/77 - Preliminary Examination Report

Patents Form 10/77 - Request for Substantive Examination

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R F Walker

Chartered Patent Attorney

Attorney for the Applicant

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Toothbrush

This invention relates to toothbrushes. In particular this invention relates to toothbrushes having means for detecting plaque and other biological deposits on the surface of teeth by directing incident radiation onto the surface of the teeth and 5 detecting fluorescence radiation emitted from the teeth in consequence.

The term "biological deposits" used herein refers generally to deposits of material of biological origin, e.g. plaque, bacteria, tartar, calculus etc. which are generally regarded as undesirable for dental hygiene. Dental plaque is a complex organic deposit generated in part by the activity of bacteria upon the teeth or upon 10 ~~contamination, e.g. food deposits on the teeth, and is an undesirable precursor to~~ tooth decay and the development of dental caries.

It is desirable to detect such deposits on the teeth before removing them, for example by toothbrushing, as detection indicates the areas at which dental cleaning effort should be concentrated. Such deposits can be difficult to detect *in situ* *in vivo* 15 on the teeth. It is especially important to detect dental plaque. For detection of plaque it is known to use fluorescence measurement, in which incident radiation is directed at the surfaces of teeth, and fluorescence radiation having characteristics associated with the presence of biological deposits is emitted from the teeth and is detected.

In the state of the art there are two general methods for detecting dental plaque, using respectively primary fluorescence in which the fluorescence of dental plaque or other dental material itself is monitored, and secondary fluorescence in which teeth suspected of bearing plaque are treated with a fluorescent label material which preferentially binds to dental plaque, and the fluorescence emission of the 20 label material at areas of the tooth at which it has bound is detected to indicate the presence of dental plaque. Patent publications WO 92/06671, WO 97/01298, US 5382163, DE 29704185, DE 29705934, EP 0774235, and also WO 97/01298 (Phillips) disclose methods of this type and apparatus for performing these methods. GB 9810471.4 filed on 16 May 1998, the contents of which are included herein by 25 way of reference, discloses a further method and apparatus for detecting biological deposits on tooth surfaces using fluorescence.

It is a requirement of such methods that incident radiation is directed at the surface of the teeth under examination and that consequent fluorescence emission radiation from the surface of the teeth is collected. WO 98/10711 discloses a toothbrush provided with a head which is made of optically transparent materials for the purpose of directing light towards the surfaces of the teeth. In WO 98/10711 this radiation is for the purposes of therapy not for detection of biological deposits.

It is an object of this invention to provide a toothbrush of the above-described type having an improved means for directing incident radiation onto the surface of teeth and for collecting fluorescence emission radiation from the surface of teeth.

According to this invention a toothbrush is provided having a handle by which it may be held, and having a head from a bristle surface of which a cluster of bristles extends in a bristle direction, the head and handle being disposed along a longitudinal axis, the toothbrush being provided with means to generate incident radiation and to direct this incident radiation toward the surface of a tooth, and being provided with means to collect emitted radiation from the surface of the tooth and to associate this emitted radiation with the presence of biological deposits on the tooth,

characterised in that the means to direct incident radiation toward the surface of a tooth, and/or the means to collect emitted radiation from the surface of the tooth comprise that the head is made at least in part of a material which is transparent to the incident and/or emitted radiation.

In general, in the toothbrush of this invention the incident radiation is directed toward the surface of the tooth in a direction generally parallel to the bristle direction, and is collected in the opposite direction. Generally the incident radiation is directed toward the surface of the tooth from part of the bristle surface. This enables the toothbrush to be held and used for brushing the teeth in a manner similar to that in which a conventional toothbrush is held and used. Generally it is preferred to locate the means to generate incident radiation and / or the means to associate this emitted radiation with the presence of biological deposits on the tooth within the handle of the toothbrush. These means will generally comprise electrical systems e.g. a light emitter and detector and associated electronics. Generally if the

means to generate incident radiation is located in the handle of the toothbrush, this incident radiation will be initially directed through the head in a direction substantially parallel to the longitudinal axis. If, as is common in toothbrushes, the bristle direction is substantially perpendicular to the longitudinal axis it will consequently be necessary to divert the radiation from a direction substantially parallel to the longitudinal axis into a direction substantially perpendicular to the longitudinal axis, i.e. into the bristle direction, and vice versa with the emitted radiation.

In a first embodiment of this invention the head of the toothbrush may be
10 made of a material which is transparent to the incident and/or emitted radiation and may thus guide radiation transmitted internally within it.

In such a construction incident radiation may be contained within the material by total internal reflection caused by the difference in refractive index ("N") between the high refractive index of the mass and the lower refractive index
15 of the surrounding air of the environment.

In this first embodiment the head may be shaped so that its shape diverts incident and emitted radiation in the above-mentioned manner. For example an end surface of the head remote from the handle, or intermediate surfaces located between this end surface and the handle, may be curved or may be angled relative
20 to the longitudinal direction and bristle direction so as to reflect, refract or otherwise divert incident radiation passing in the longitudinal direction along the head into the bristle direction. Additionally or alternatively the material may be coated, either wholly or partially, with a reflective coating, e.g. a thin reflective metal layer, so as to reflect incident radiation passing in the longitudinal direction
25 along the head into the bristle direction. The shape and size of such surfaces, and/or of the reflective coating may be used to determine the area onto which incident radiation is directed and from which emitted radiation is collected. Additionally or alternatively the material itself or the above-mentioned reflective coating may be covered with a non-transparent layer, for example to prevent loss of incident or
30 emitted radiation, or entry of extraneous radiation. If such a toothbrush head is manufactured by the usual process of injection moulding, then care should be taken

to ensure that there is no formation of cloudiness, streaks or bubbles which might interfere with the transmission of radiation through the head material.

In this first embodiment the structure of the toothbrush head, i.e. the material into which the toothbrush bristles are fixed, may comprise the material which is transparent to the incident and/or emitted radiation.

In this first embodiment, particularly if the structure of the toothbrush head comprises the material which is transparent to the incident and/or emitted radiation, the head may also incorporate one or more additional radiation guiding means, for example one or more optical fibres (e.g. of known type), to direct incident and/or emitted radiation respectively to and from the tooth surface. For example one or more such means, e.g. optical fibres may extend through the bristle surface and may direct incident radiation to the tooth surface, and the transparent material may collect emitted radiation through the bristle surface. Alternatively for example the transparent material may direct incident radiation to the tooth surface, and one or more such means, e.g. optical fibres extending through the bristle surface may collect emitted radiation. Alternatively for example such optical fibre(s) may end in the transparent material below the surface of the head, for example such fibre(s) may end below the bristle surface and facing in the bristle direction. Incident radiation may consequently pass through a transparent layer or window of the head after leaving the end of the fibre, and may then reach the tooth surface. Additionally or alternatively emitted radiation from the tooth surface may consequently pass through a transparent layer or window of the head before reaching the end of the fibre.

In a second embodiment of this invention the head of the toothbrush may comprise one or more cores of material which is transparent to the incident and/or emitted radiation, which may guide radiation transmitted internally within it, and having a refractive index N^1 , the core being surrounded by a sheath which is also of material which is transparent to the incident and/or emitted radiation, the sheath having a refractive index N^2 , N^1 being greater than N^2 , such that internal reflection occurs as a result of the difference in refractive index between N^1 and N^2 to direct radiation within the core.

The sheath may comprise a material which forms the structure of the toothbrush head, or alternatively the core(s) and sheath may themselves be encased within the toothbrush head, for example being encased within a material which comprises the structure of the toothbrush head. If the core and sheath are formed by injection moulding, then care should be taken to ensure that there is no formation of cloudiness, streaks or bubbles etc. which might interfere with the transmission of radiation through the core or sheath. For example the core may be made first, e.g. by injection moulding then the sheath may be moulded around the core by a second injection moulding process. In this last mentioned procedure care should be taken that the sheath and core materials have identical or similar shrinking values as they cool after the injection moulding process to ensure that no cracks form due to differential contraction.

In this second embodiment the core(s) may be shaped so that its/their shape diverts incident and emitted radiation in the above-mentioned manner. For example an end surface of the core(s) remote from the handle, or intermediate surfaces located between this end surface and the handle may be curved or may be angled relative to the longitudinal direction and bristle direction so as to reflect, refract or otherwise divert incident radiation passing in the longitudinal direction along the head into the bristle direction. Additionally or alternatively the core(s) may be coated, either wholly or partially, with a reflective coating, e.g. a thin reflective metal layer, so as to reflect incident radiation passing in the longitudinal direction along the head into the bristle direction. Such a thin reflective metal layer may be in the form of a foil which can be attached to a pre-formed head or core component during the manufacturing process. If for example such a reflective metal layer is attached to a pre-formed core, around which the head or a sheath is formed by a subsequent injection moulding step, care should be taken to ensure that the metal layer does not become loosened, detached or distorted during the moulding formation of the head material.

In this second embodiment a core may have a surface which is substantially perpendicular to the bristle direction, so that incident radiation passing along the core may emerge from the core through this surface and from thence be directed to

the tooth surface. Conversely emitted radiation from the tooth surface may enter the core through this surface and may be directed through the core.

The core may extend through the sheath material so that the core is exposed outside of the toothbrush head so that radiation may pass directly from the core to the tooth surface and vice versa. Alternatively radiation passing through the core may need to pass through the sheath material, or through parts of the toothbrush head on its way to and from the tooth surface.

One or more of the toothbrush bristles may comprise (a) radiation guide(s) to guide radiation to and from the tooth surface to the toothbrush head, (b) a bristle functioning as an optical fibre to guide the radiation to the tooth surface from the head, and/or in the reverse direction.

When the bristles are used in this way it is preferred that the bristles which are fixed into the toothbrush head are fixed into the toothbrush head in a manner which allows radiation to pass from the toothbrush head within the toothbrush head into the bristles and vice versa. For example, the bristles may be fixed into the head by means of a process of welding, or by being embedded in a liquid hardenable substance, so that a good optical connection is made between the head and the bristle. Suitable processes to achieve this are known in the state of the art, for example WO 95/31917 and WO 97/39649. In such a process the ends of individual bristles or bundles of bristles which are fixed into the toothbrush head may be thermally fused so that a "mushroom head" is formed in the toothbrush head. Furthermore if the mushroom head is formed in this way care should be taken that the mushroom head and/or the adjacent ends of the bristles do not become opaque or translucent but remain transparent to the exciting radiation and/or emitted fluorescence radiation. Some such known processes, e.g. that of WO 97/39649 may enable bristles to be fixed into the head with fixed ends which have end surfaces which are generally perpendicular to the lengthwise direction of the bristles, facilitating transmission of light from the head material to the bristles.

Alternatively the toothbrush bristles may alternatively be fixed into the toothbrush head in the conventional manner in which a number of bristles folded in two lengthwise then a small metal clip or "anchor" is fastened around the bundle so formed, and the clip is jammed into a fixing hole in the toothbrush head. In this

case it may be necessary to cut, polish or grind the region of the fold so that a good optical connection is made between the head and the bristle.

In the toothbrush of this invention the bristles may be co-extruded bristles, i.e. comprising an inner core of a first polymer, surrounded by a sheath of a second polymer. For example the inner core may be a soft elastomer and the sheath may be of a harder plastic material. Toothbrush bristles of this type are disclosed inter alia in WO97/14830 and in PCT/EP98/00718. In one embodiment such co-extruded bristles may comprise (a) radiation guide(s) to guide radiation to and from the tooth surface to the toothbrush head as described above.

1.1 ~~Additionally or alternatively the toothbrush head may be provided with other~~ radiation guides to guide radiation to and from the tooth surface to the toothbrush head.

For example the bristle surface may be provided with one or more bristle free areas which function as windows for radiation passing to and from the tooth surface to the toothbrush head. For example additionally or alternatively the toothbrush head may be provided with lenses for radiation passing to and from the tooth surface to the toothbrush head which focus emitted radiation from the toothbrush head onto the tooth surface and/or which focus or collect emitted radiation from the tooth surface toward the above-mentioned radiation guiding means or the above-mentioned core.

1.2 Suitable transparent materials which are transparent to the incident and/or emitted radiation include known transparent plastic materials. If the bristles of the toothbrush are to be used as radiation guides then these should be made of fibre materials which are sufficiently transparent to the incident and/or emitted radiation of interest.

1.3 Suitably in the toothbrush of this invention the incident radiation may be of a wavelength known from the state of the art referred to above which excites fluorescence emission from biological deposits on tooth surfaces, and/or from deposit-free tooth surfaces, and the emitted radiation may be of a wavelength known from the state of the art to correspond to fluorescence emission from such surfaces.

1.4 Suitably the incident radiation may have a wavelength between 430 and 500 nm and the emitted radiation may have a wavelength above 520 nm. Although incident radiation of wavelength below 430 nm may be more effective at exciting

fluorescence emission from biological deposits or tooth surfaces than higher wavelength radiation, this lower wavelength radiation may be harmful to mouth tissues.

The toothbrush is also provided with means to generate incident radiation and to direct this incident radiation toward the surface of a tooth. This may comprise a suitable radiation source, for example a light emitting diode of known type. The means to associate the emitted radiation with the presence of biological deposits on the tooth may comprise a conventional detector e.g. a semiconductor photodiode. It may be appropriate to incorporate optical filters, e.g. dichroic mirrors, into the optical path between the detector and the test tooth surface to ensure that emitted radiation of a suitable wavelength is preferentially received by the detector. These means, and an appropriate power supply, electronic processing devices, and means to signal the presence and/or absence of biological deposits on a tooth surface may conveniently be provided within the handle of the toothbrush. Suitable means for these purposes will be apparent to those skilled in the art, and are disclosed in the state of the art.

Conveniently the head of the toothbrush of the invention may be made detachable from the handle of the toothbrush. This is particularly convenient if the handle, as described above, includes the radiation source etc., so that the head can be replaced when for example its bristles become worn out without the need to also replace these relatively expensive electrical components. If the head of the toothbrush is detachable from the handle the joint between the head and handle should comprise an optical connector.

The toothbrush of the present invention is particularly suited for use in the apparatus and method disclosed in GB 9810471.4 filed on 16 May 1998, the contents of which are included herein by way of reference. The apparatus disclosed therein comprises;

illumination means to direct exciting radiation onto a test tooth surface,
detection means to detect fluorescence emission from the test tooth surface at
a wavelength associated with that of auto fluorescence emission from a substantially biological deposit-free tooth surface,



means to make a comparison of the intensity of the auto fluorescence emission from the test tooth surface with an intensity of auto fluorescence emission associated with auto fluorescence emission from a substantially biological deposit-free tooth surface,

means to associate the comparison thus obtained with the presence of biological deposits on the test tooth surface, and,

indicator means to indicate the presence of such biological deposits to a user of the apparatus.

The toothbrush of this invention will now be described by way of example
10 only with reference to the accompanying figures, of which:

Figs. 1 to 9 show longitudinal sections through heads of toothbrushes of this invention.

Fig. 10 shows a schematic longitudinal section through a handle of a toothbrush of this invention.

15 Figs. 11A, 11B, 11C and 11D show cross sections through bundles of bristles of the toothbrush of this invention being used as radiation guides.

Referring to Fig. 1 a toothbrush head 1 is shown. The head is detachably connectable to a handle (not shown) by means of connector means 2, which may be conventional in the art. The head 1 and the toothbrush handle are disposed along a longitudinal axis A--A. From a bristle surface 3 of the head 1 extends a cluster of bristles 4, extending in a bristle direction B--B. The head 1 is made of a mass of plastic material which is transparent to radiation in the wavelength region at least between 400-600 nm. The ends 4A of the bristles 4 which are fixed into the head 1 are welded into the head 1 material as individual filaments by a state of the art process.

Incident radiation may be directed from a source (not shown in Fig. 1) into the head 1 from the direction of the handle, i.e. in the direction shown by the arrow 5, by means of an optical connection surface 6, being a planar surface of the transparent material of which the head 1 is made. Because of internal reflection within the transparent head resulting from the difference in refractive index between the high refractive index N_1 of the head material and the lower refractive index N_2 of the surrounding air, this radiation is directed through the head 1 and emerges

from the head 1 via the bristle face 3, i.e. substantially in the bristle direction B--B. The radiation emerging from the bristle face 3 impinges upon the surface of a tooth (not shown) and excites fluorescence emission from biological deposits on the tooth surface and/or deposit-free tooth surfaces. This emitted radiation traveling in the direction shown by the arrow 7 passes through the bristle face 3 and is collected by the transparent head 1. As before, internal reflection within the transparent head, causes the emitted radiation to be directed in the direction toward the handle, i.e. in the direction 7.

Referring to Fig 2, features common in construction with Fig. 1 are numbered correspondingly. In this embodiment an end surface 8 of the head 1 remote from the handle is angled relative to the longitudinal direction A--A and bristle direction B--B so as to reflect incident radiation passing in the longitudinal direction A--A along the head 1 into the bristle direction B--B. This end surface 8 is coated with a reflective coating 9, being a thin reflective metal layer, so as to reflect incident radiation passing in the longitudinal direction along the head into the bristle direction. The coating 9 is a thin reflective metal foil applied to the head material 1 by hot stamping. As in the embodiment of Fig. 1 The radiation emerging from the bristle face 3 impinges upon the surface of a tooth (not shown) and excites fluorescence emission from biological deposits on the tooth surface and/or deposit-free tooth surfaces. This emitted radiation traveling in the direction shown by the arrow 7 passes through the bristle face 3 and is collected by the transparent head 1 and is reflected at the surface 8 along the longitudinal direction A--A toward the handle. As before, internal reflection within the transparent head, causes the emitted radiation to be directed in the direction toward the handle, i.e. in the direction 7A.

Referring to Figs. 3, 4 and 5, features common in construction with Fig. 1 are numbered correspondingly. Within the mass of transparent material of the head 1 are located optical fibres 10, 11, 12, 13 of conventional type.

These fibres 10, 11, 12, 13, direct incident and/or emitted radiation respectively to and from the tooth surface. As shown in Fig. 3 an optical fibre or bundle of optical fibres 10 extends through the surface of the transparent mass 1 in the bristle direction B--B and directs incident radiation to the tooth surface (not shown) in the direction shown by the arrow 5. The mass of transparent material 1

collects emitted radiation, and as described with reference to Figs. 1 and 2 directs this emitted radiation back in the direction of the handle, i.e. the direction shown by arrow 7. Alternatively the mass of transparent material 1 may direct incident radiation to the tooth surface, and the optical fibre(s) 10 extending through the surface of the mass may collect emitted radiation and direct it back toward the handle.

As shown in Figs. 4 and 5, optical fibres or bundles of optical fibres 11, 12, 13 end in the mass of transparent material below the bristle surface, facing in the bristle direction B--B. Incident radiation passing in the direction of the handle 10 consequently passes through a transparent layer or window 14 of the mass after leaving the end of the fibre(s), and may then reach the tooth surface. Similarly emitted radiation from the tooth surface passes through this transparent layer 14 before reaching the end of the fibre. In Fig. 4 a single fibre or bundle 11 is used to direct radiation from the direction of the handle toward the tooth surface, and the transparent mass of head material 1 collects the emitted radiation, or vice versa. In Fig. 5 two fibres or bundles are used, one to direct incident radiation toward the tooth surface and the other to collect emitted radiation and direct it toward the handle.

At surface 6 the optical fibres or bundles of fibres 10, 11, 12, 13 ends with a suitable optical connection surface.

Referring to Fig 6, features common in construction with Fig. 1 are numbered correspondingly. The head 1 of the toothbrush comprises a core 15 of material which is transparent to the incident and/or emitted radiation, which can guide radiation transmitted internally within it, and having a refractive index N^1 . The core 15 may be made by injection moulding in a first moulding operation, and then the head 16 may be injection moulded around the core 15, care being taken during this second moulding operation to ensure that the so formed core 15 does not crack, soften, distort or otherwise become distorting to light transmission.

This core 15 extends within the head 1 of the toothbrush in the longitudinal direction A--A. The core 15 is surrounded by a sheath 16 which is also of material which is transparent to the incident and/or emitted radiation, the sheath having a refractive index N^2 , N^1 being greater than N^2 . Internal reflection occurs as a result

of the difference in refractive index between N^1 and N^2 to direct radiation within the core, so that incident radiation passing in the direction 5 and collected emitted radiation passing in the direction 7 are contained within the core 15 and directed toward the handle. The sheath comprises a mass of material which forms the structure of the toothbrush head and from which the bristles 4 extend.

An end surface 17 of the core remote from the handle is angled relative to the longitudinal direction A--A and bristle direction B--B so as to reflect incident radiation passing in the longitudinal direction along the head into the bristle direction. Additionally the surface 17 may be coated with a reflective coating, being a thin reflective metal layer, e.g. a foil applied by hot stamping as above, so as to reflect incident radiation passing in the longitudinal direction along the head into the bristle direction. At its end 18 remote from the handle the core 15 ends with a surface which is substantially perpendicular to the bristle direction B--B, so that incident radiation passing along the core in direction 5 may emerge from the core through this surface and from thence be directed to the tooth surface. Similarly emitted radiation from the tooth surface is collected by the core 15 and directed toward the handle in direction 7. The incident and emitted radiation therefore passes through the layer 14 of transparent material of the head 1. At surface 6 the core ends with a suitable optical connection surface.

Referring to Fig. 7, features common in construction with Fig. 1 are numbered correspondingly. A toothbrush head has a core 15 surrounded by a sheath 16, with differing refractive indices, the sheath 16 having a refractive index N^2 , the core 15 having a refractive index N^1 being greater than N^2 , similar in construction and operation to that of Fig. 6. As shown in Fig. 7 there are a number of intermediate surfaces 19 which are angled relative to the longitudinal direction A--A and the bristle direction B--B so as to reflect incident radiation passing in the longitudinal direction along the head into the bristle direction. These intermediate surfaces 19 may be coated with a reflective coating.

The surface 18 of the core 15 is parallel to the bristle face, and perpendicular to the bristle direction B--B, and incident radiation and emitted radiation are respectively directed to and collected from the tooth surface through

surface 18 and the transparent window layer 14. At surface 6 the core ends with a suitable optical connection surface.

Referring to Fig. 8, features common in construction with Fig. 1 are numbered correspondingly. A toothbrush head 1 having a core 15 similar in construction and function to that shown in Fig 6 is illustrated. In Fig. 8 the core 15 extends through the sheath material 16 so that the core is exposed at surface 20 outside of the toothbrush head 1 so that radiation may pass directly from the core to the tooth surface and vice versa. Additionally the toothbrush head 1 is provided with a bristle free area 21 which functions as a window for radiation passing to and from the tooth surface to the toothbrush head 1 into the core 15. At surface 6 the core ends with a suitable optical connection surface.

Referring to Fig. 9, features common in construction with Fig. 1 are numbered correspondingly. A toothbrush head 1 having a core 15 similar in construction and function to that shown in Fig. 6 is illustrated. In Fig. 9 the toothbrush head 1 is provided with a bristle free area 21 which functions as a window for radiation passing to and from the tooth surface to the toothbrush head 1 into the core 15. Additionally a lens 22 of transparent material is provided in the optical pathway between the end 18 of the core 15 and the tooth surface. This lens 22 focuses incident radiation emerging from surface 18 toward the tooth surface, and also assists the collection of emitted radiation from the tooth surface and the directing of this emitted radiation along core 15 toward the handle of the toothbrush. At surface 6 the core ends with a suitable optical connection surface.

Referring to Fig 10, a schematic diagram of the handle 23 of the toothbrush of this invention, suitable for use with the toothbrush heads of Figs. 6-9 is shown.

The toothbrush handle 23 is provided with a connector 24 enabling connection with the connectors 2 of the heads of Figs 1-9. The handle 23 includes an incident radiation source 25 being a light emitting diode of known type, for example capable of emitting radiation of wavelength in the range 430-500 nm. The handle 23 also includes a radiation detector 26 being a semiconductor photodiode. The handle 23 also includes a power supply 27, a control 28, electronic processing devices 29, and signaling means 30 to signal the presence and/or absence of biological deposits on a tooth surface, for example a light or buzzer etc.. The toothbrush handle 23 also

includes a set of dichroic mirrors 31, 32 which reflect incident radiation from source 25, but transmit emitted radiation so that these follow divergent radiation pathways. This enables the emitted radiation to be collected by the detector 26. Although illustrated in Fig 10 for embodiments having a core 15, corresponding constructions suitable for use with embodiments as in Figs 1-5 having optical fibres will be apparent to those skilled in the art. The respective end surfaces of the handle 23 and a head e.g. as shown in Figs. 1-9 should mate with precision such that there is as little loss of radiation as possible which passes between the head 1 and handle 23.

Referring to Figs. 11A, 11B, 11C and 11D constructions of bundles of bristles of a toothbrush of this invention are shown.

In Fig. 11A a bundle of bristle fibres 4, made of a fibre material which is transparent to incident radiation, has been fixed into the material of a toothbrush head 1 so that they extend from the bristle face 3 by means of a state of the art welding process which has melted the ends of the bundle of bristles 4 into a mass 33, which is itself fused with the material of the head 1. The fused mass 33 enables incident radiation to pass in the direction 5 from the head 1 material into the bristles 4, and emitted radiation to be collected in the opposite direction. The fused mass 33 may be shaped into a lens shape to assist in guiding radiation into and out of the bristles 4. In Fig. 11B an analogous situation is shown in which a single bristle or "monofilament" bristle is fixed into the toothbrush head, for example using a process as disclosed in WO 97/39649, and the end 33 of a single such bristle is fused into a lens shape.

In Figs. 11C and 11D bristles 4 are fixed into the toothbrush head 1 in the conventional manner by folding each bristle 4 in two and fastening a small metal clip or "anchor" 34 around the folded bristles near the fold. The anchor is then jammed into a fixing hole 35 in the bristle face. In Figs. 11C and 11D only one of the bristles included in the bristle bundle is shown. As shown in Fig. 11C it is difficult for incident radiation and emitted radiation to pass in their respective directions 5 and 7 between the head 1 material and the bristle 4. In Fig. 11D the region 36 of the outside bend of the fold has been polished or ground, thereby

creating a flat surface which facilitates transmission of incident and emitted radiation between the head 1 and bristles 4.

In use the toothbrush of the invention is used to brush the user's teeth, thereby aligning the bristle face 3 so that it faces the tooth surface at a convenient distance. The control 28 is operated, and incident radiation is directed in the direction 5 from the source 25, being reflected by dichroic mirrors 31, 32 onto a tooth surface using the toothbrush head 1 of this invention. Fluorescence radiation is emitted from the tooth surface, either from biological deposits such as plaque or from a deposit-free tooth surface or from both. This emitted radiation is collected 10 by ~~the head 1 and directed back as described above to the detector 26, being~~ transmitted through the dichroic mirror 32. An electrical signal is generated by the detector 26 and is processed by the processing device 29. The processing device 29 operates the signaling means 30 to indicate to the user the presence or absence of biological deposit.

Claims.

1 A toothbrush having a handle by which it may be held, and having a head from a bristle surface of which a cluster of bristles extends in a bristle direction, the
5 head and handle being disposed along a longitudinal axis, the toothbrush being provided with means to generate incident radiation and to direct this incident radiation toward the surface of a tooth, and being provided with means to collect emitted radiation from the surface of the tooth and to associate this emitted radiation with the presence of biological deposits on the tooth,

10 characterised in that the means to direct incident radiation toward the surface of a tooth, and/or the means to collect emitted radiation from the surface of the tooth comprise a the head made at least in part of a material which is transparent to the incident and/or emitted radiation.

2. A toothbrush according to claim 1 characterised in that the head of the
15 toothbrush is made of a material which is transparent to the incident and/or emitted radiation guides radiation transmitted internally within it.

3. A toothbrush according to claim 2 characterised in that the head is shaped so that its shape diverts incident and emitted radiation.

4. A toothbrush according to claim 3 characterised in that an end surface of the
20 head remote from the handle, or intermediate surfaces located between this end surface and the handle, are curved or angled relative to the longitudinal direction and bristle direction so as to reflect, refract or otherwise divert incident radiation passing in the longitudinal direction along the head into the bristle direction.

5. A toothbrush according to any one of claims 2 to 4 characterised in that the
25 head is coated with a reflective coating which reflects incident radiation passing in the longitudinal direction along the head into the bristle direction.

6. A toothbrush according to any one of claims 2 to 5 characterised in that the head incorporates one or more additional radiation guiding means to direct incident and/or emitted radiation respectively to and from the tooth surface.

30 7. A toothbrush according to claim 6 characterised in that such radiation guiding means comprise one or more optical fibres which extend through the bristle surface.



8. A toothbrush according to claim 6 characterised in that such radiation guiding means comprise one or more optical fibres which end in the transparent material of the head below the bristle surface and facing in the bristle direction.
9. A toothbrush according to claim 1 characterised in that the head of the toothbrush comprises one or more cores of material which is transparent to the incident and/or emitted radiation, and having a refractive index N^1 , the core being surrounded by a sheath which is also of material which is transparent to the incident and/or emitted radiation, the sheath having a refractive index N^2 , N^1 being greater than N^2 , such that internal reflection occurs as a result of the difference in refractive index between N^1 and N^2 to direct radiation within the core.
10. A toothbrush according to claim 9 characterised in that the core(s) is/are shaped so that its/their shape diverts incident and emitted radiation.
11. A toothbrush according to claim 10 characterised in that an end surface of the core(s), or an intermediate surface located between this end surface and the handle is curved or angled relative to the longitudinal direction and bristle direction so as to reflect, refract or otherwise divert incident radiation passing in the longitudinal direction along the head into the bristle direction.
12. A toothbrush according to claim 10 or 11 characterised in that the core is coated with a reflective coating so as to reflect incident radiation passing in the longitudinal direction along the head into the bristle direction.
13. A toothbrush according to any one of claims 10 to 12 characterised in that the core extends through the sheath material so that the core(s) is/are exposed outside of the toothbrush head.
14. A toothbrush according to any one of the preceding claims characterised in that one or more of the toothbrush bristles comprises a radiation guide s to guide radiation to and from the tooth surface to the toothbrush head.
15. A toothbrush according to any one of the preceding claims characterised in that the bristle surface is provided with one or more bristle free areas which function as windows for radiation passing to and from the tooth surface to the toothbrush head.

16. A toothbrush according to any one of the preceding claims characterised in that the toothbrush head is provided with lenses for radiation passing to and from the tooth surface to the toothbrush head.

17. A toothbrush according to any one of the preceding claims characterised in that the material which is transparent to the incident radiation is transparent to radiation of wavelength in the range between 430 and 500 nm.

18. A toothbrush according to any one of the preceding claims characterised in that the material which is transparent to the emitted radiation is transparent to radiation of wavelength in the range above 520 nm

19. ~~A toothbrush according to any one of the preceding claims characterised in~~ that the head of the toothbrush of the invention is detachable from the handle of the toothbrush.

20. A toothbrush according to any one of the preceding claims characterised by comprising;

15 illumination means to direct exciting radiation onto a test tooth surface,
detection means to detect fluorescence emission from the test tooth surface at a wavelength associated with that of auto fluorescence emission from a substantially biological deposit-free tooth surface,

means to make a comparison of the intensity of the auto fluorescence
emission from the test tooth surface with an intensity of auto fluorescence emission associated with auto fluorescence emission from a substantially biological deposit-free tooth surface,

20 means to associate the comparison thus obtained with the presence of biological deposits on the test tooth surface, and,

25 indicator means to indicate the presence of such biological deposits to a user of the apparatus.

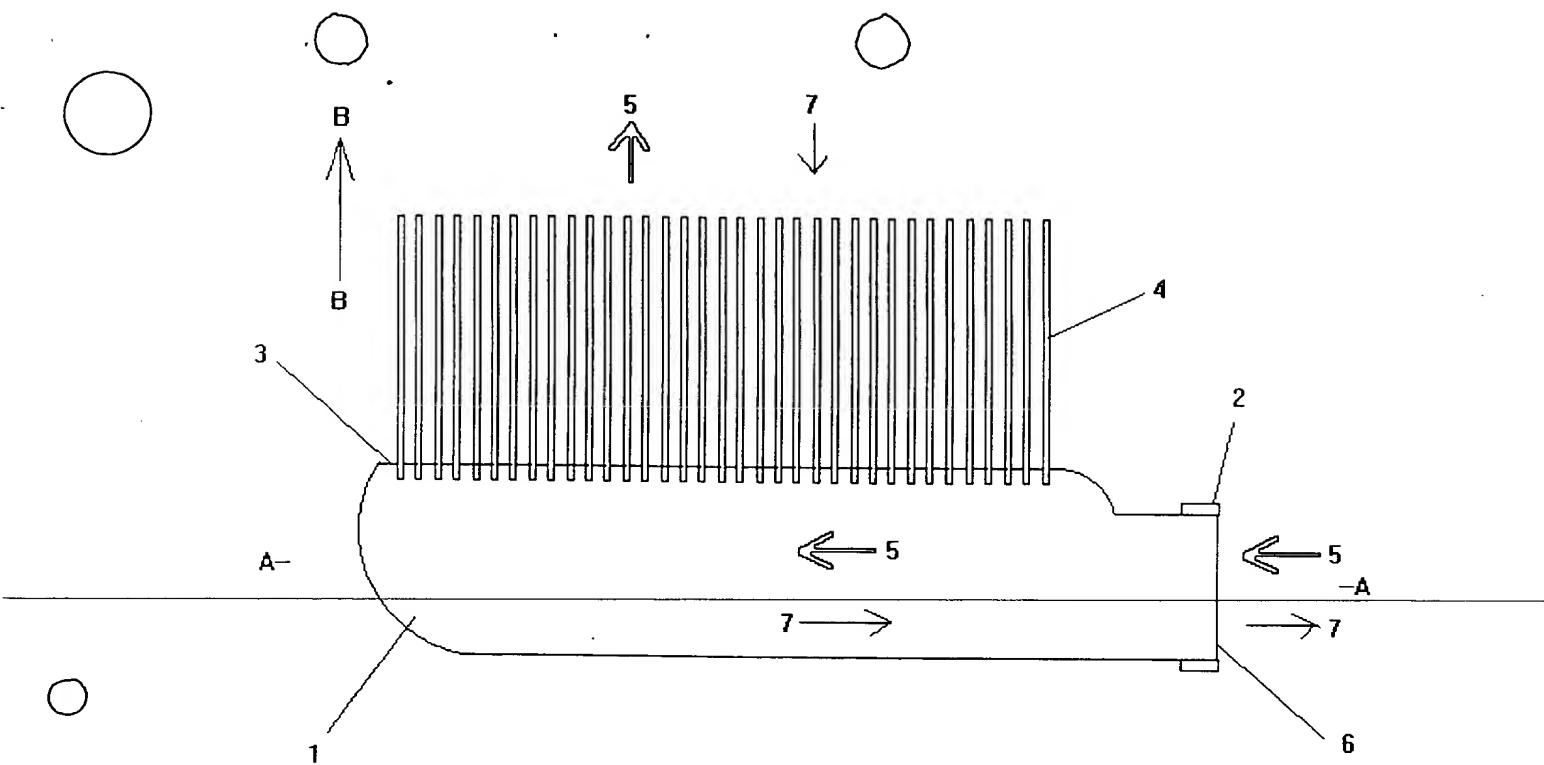


FIG. 1

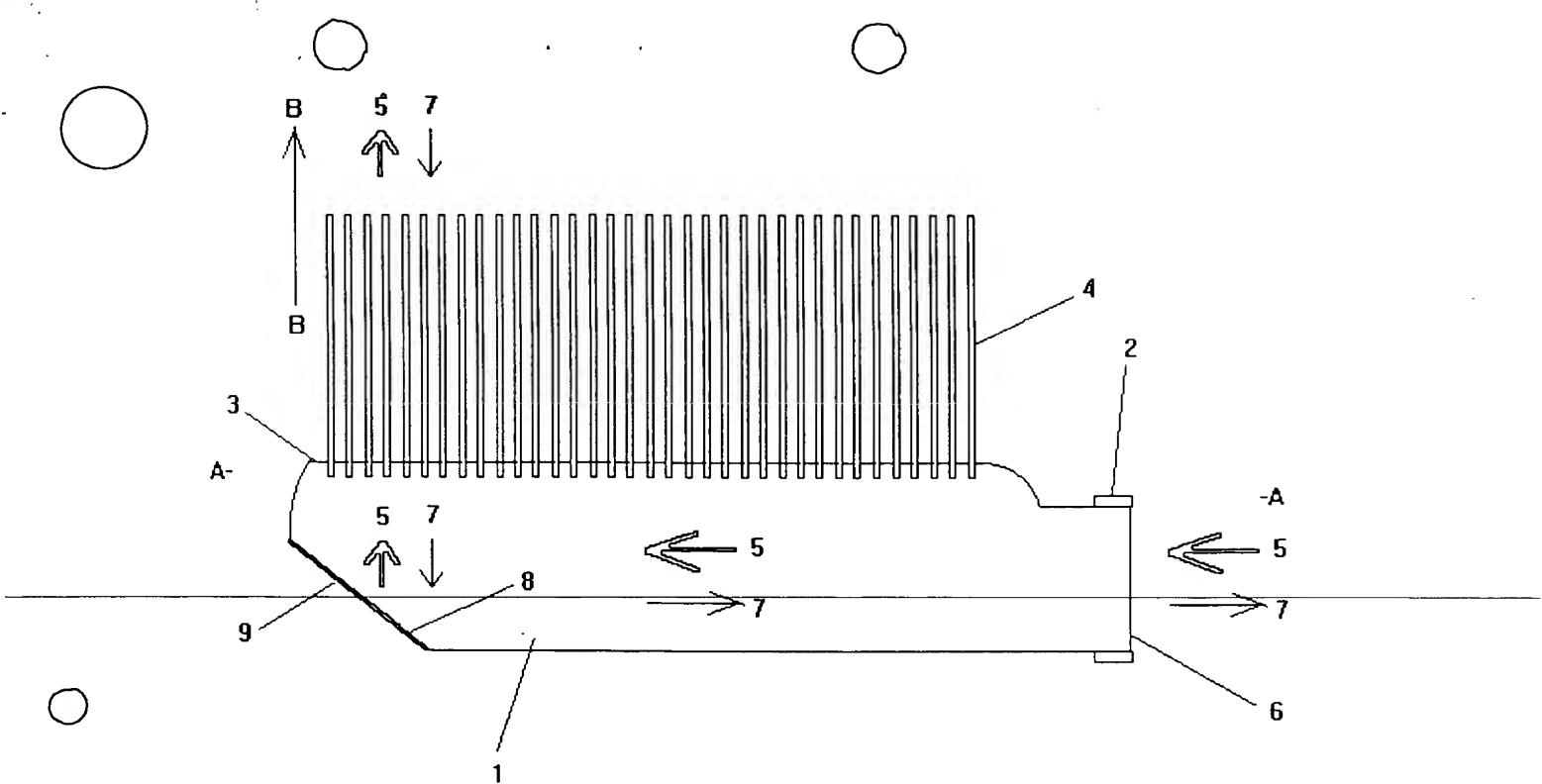


FIG. 2

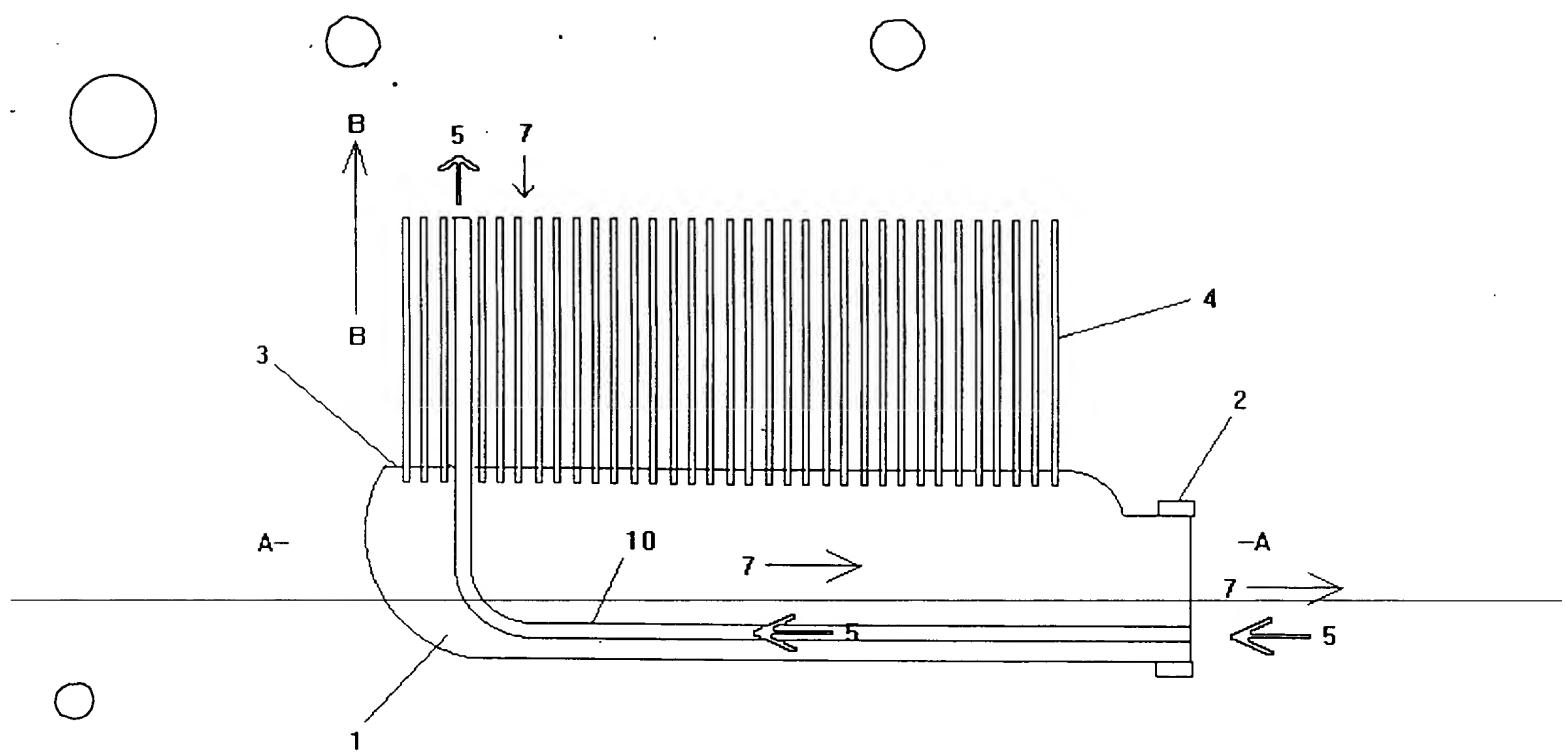


FIG. 3

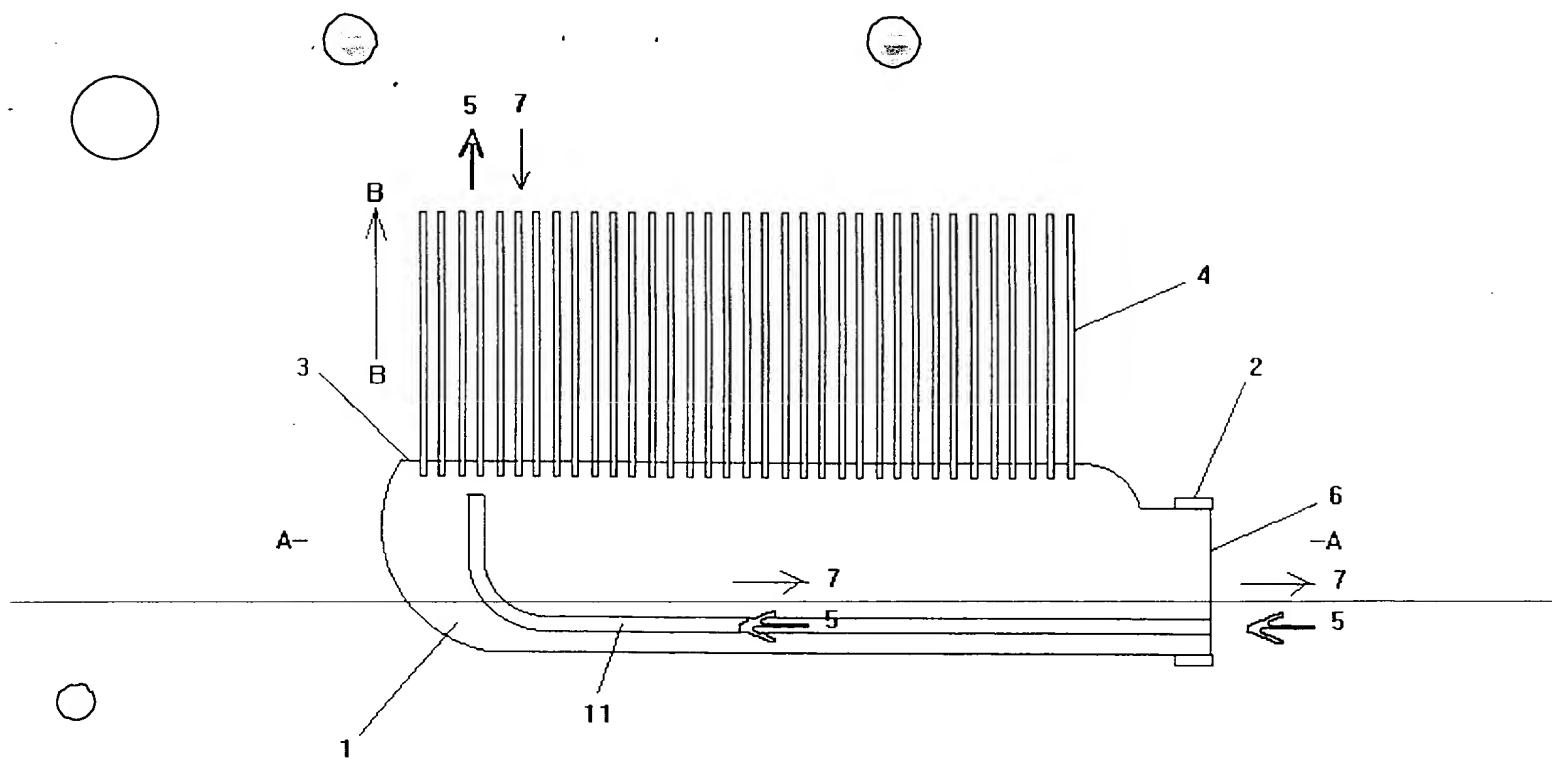


FIG. 4

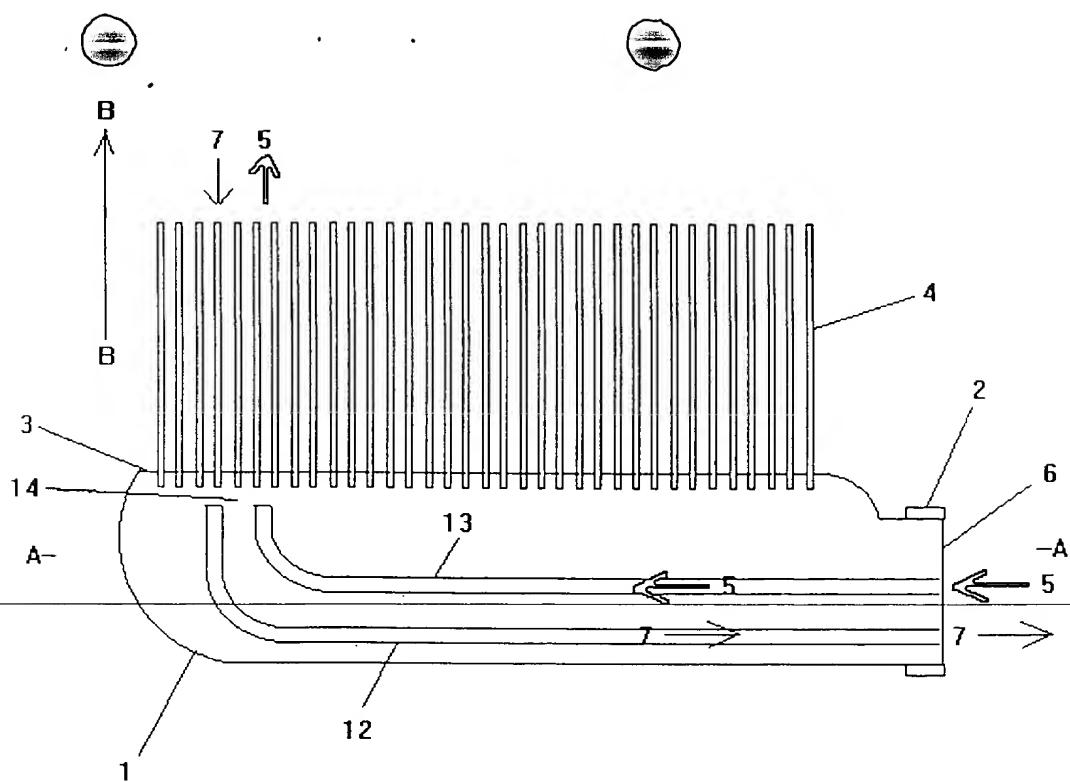


FIG. 5

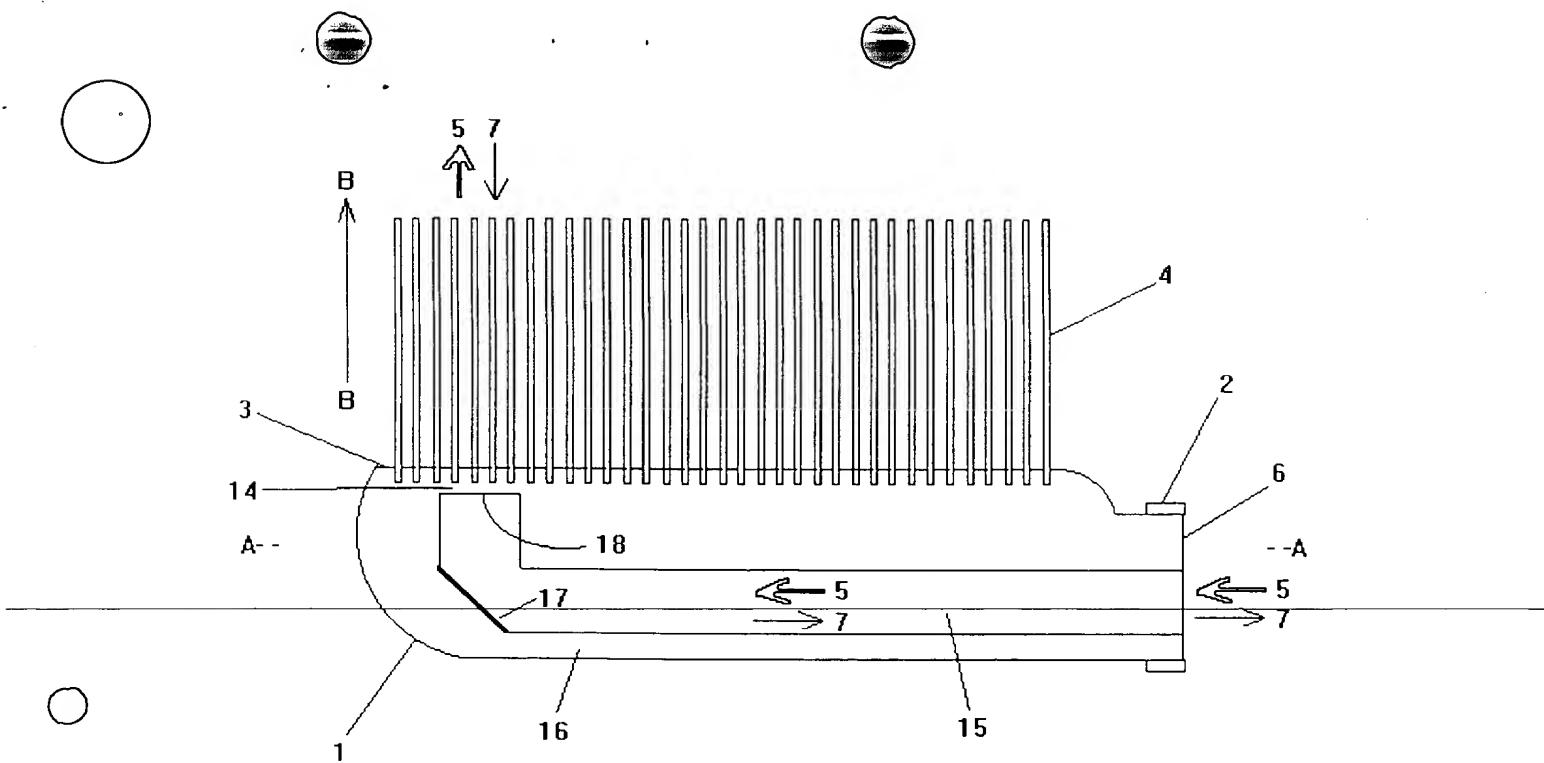


FIG. 6

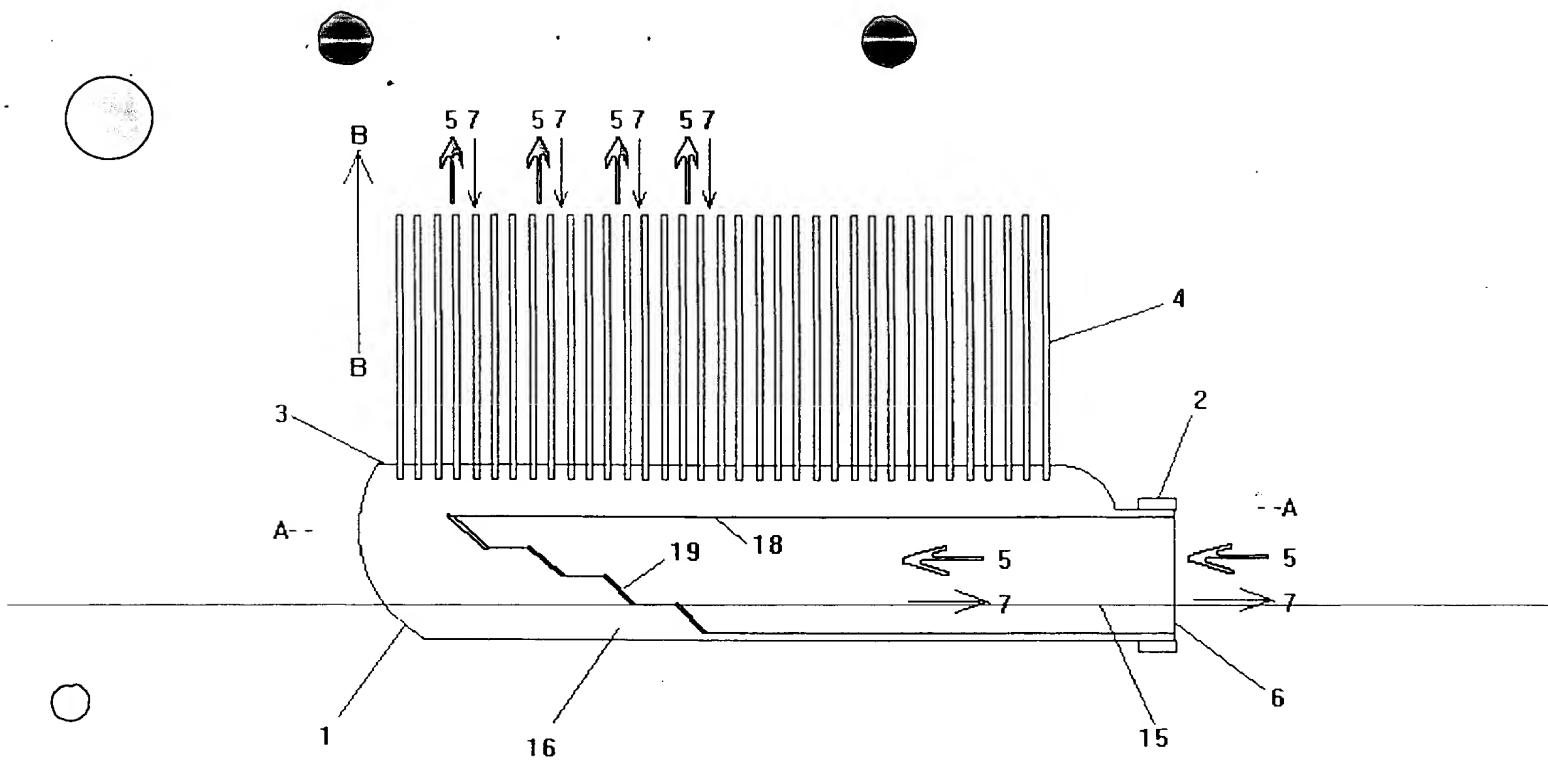


FIG. 7

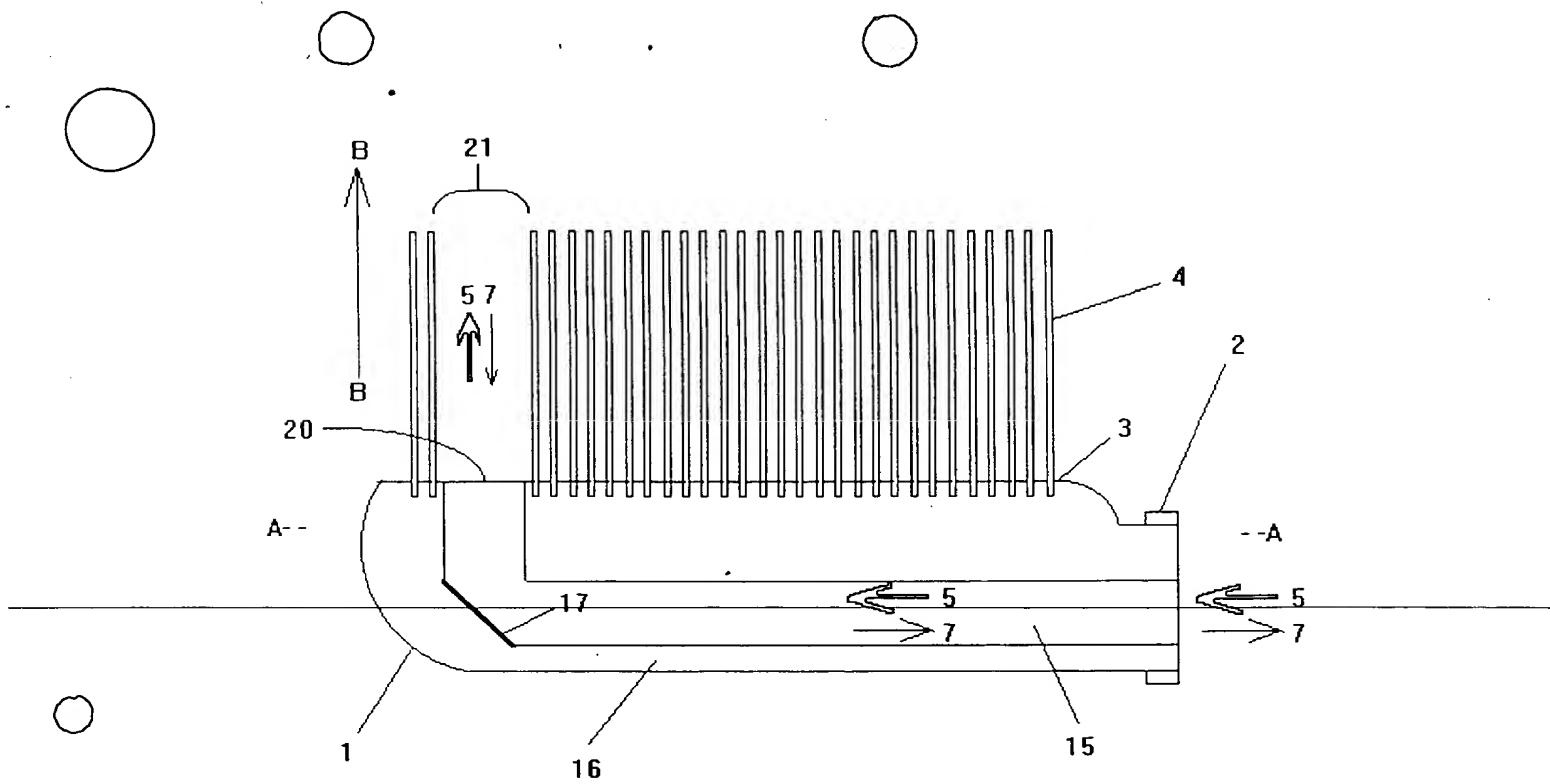


FIG. 8

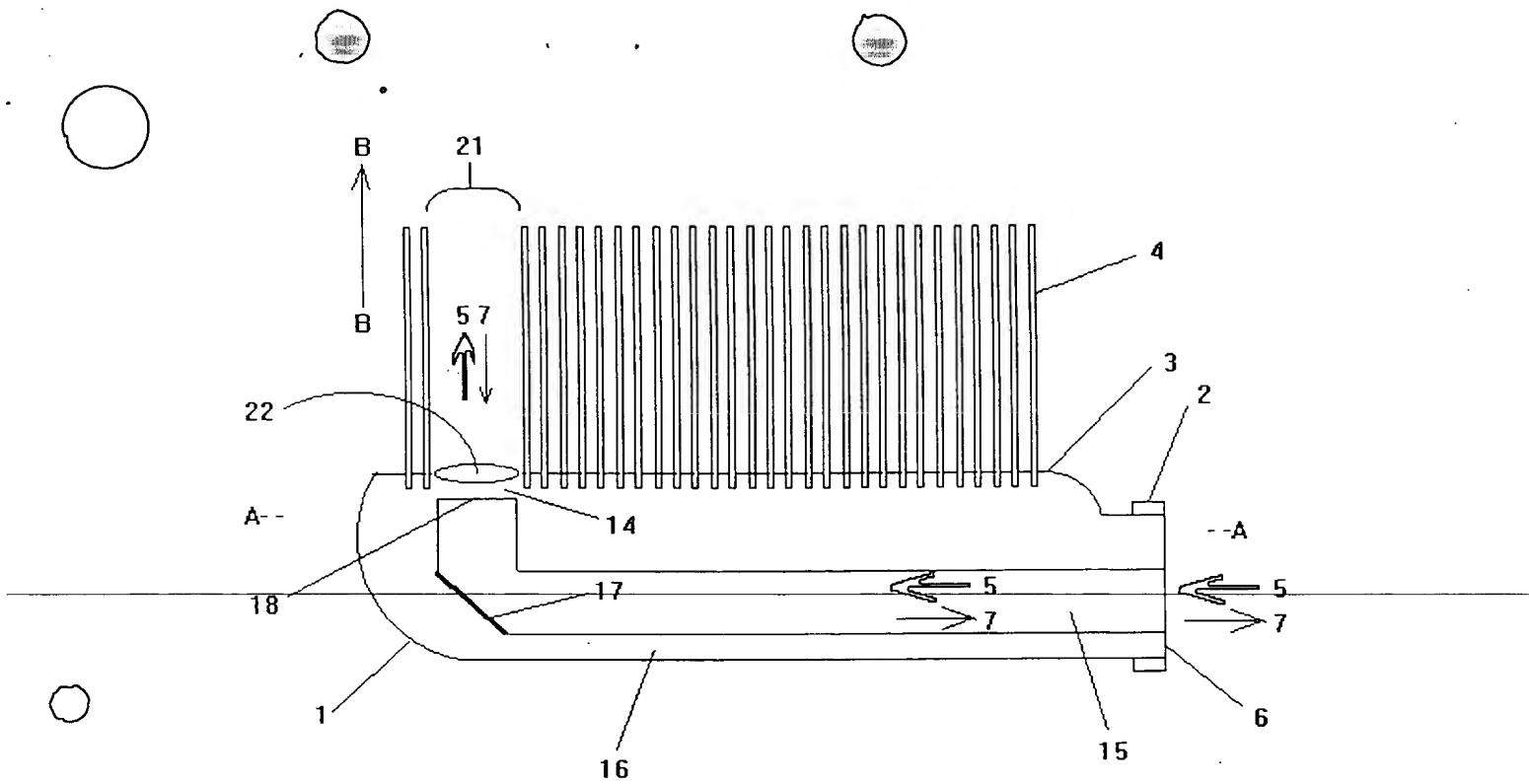


FIG. 9

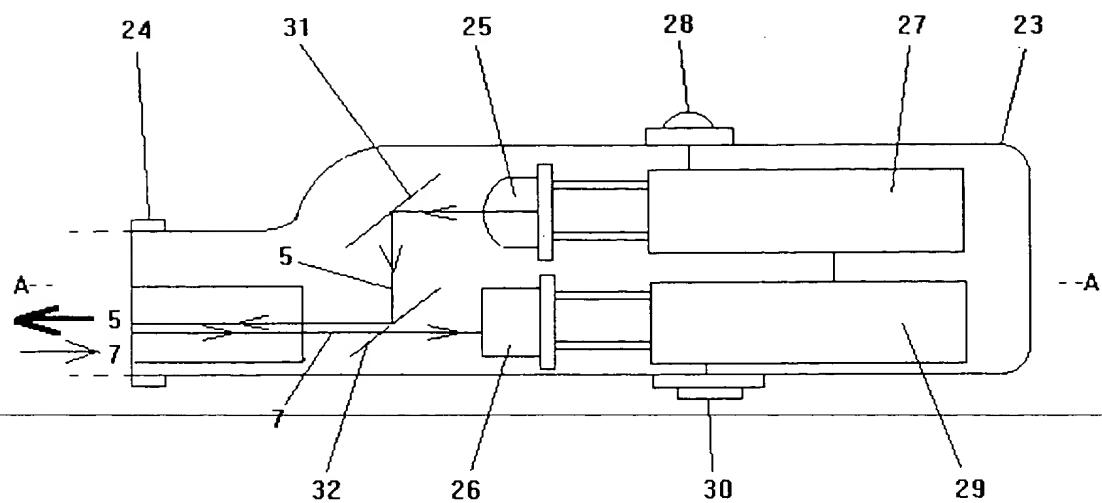


FIG. 10

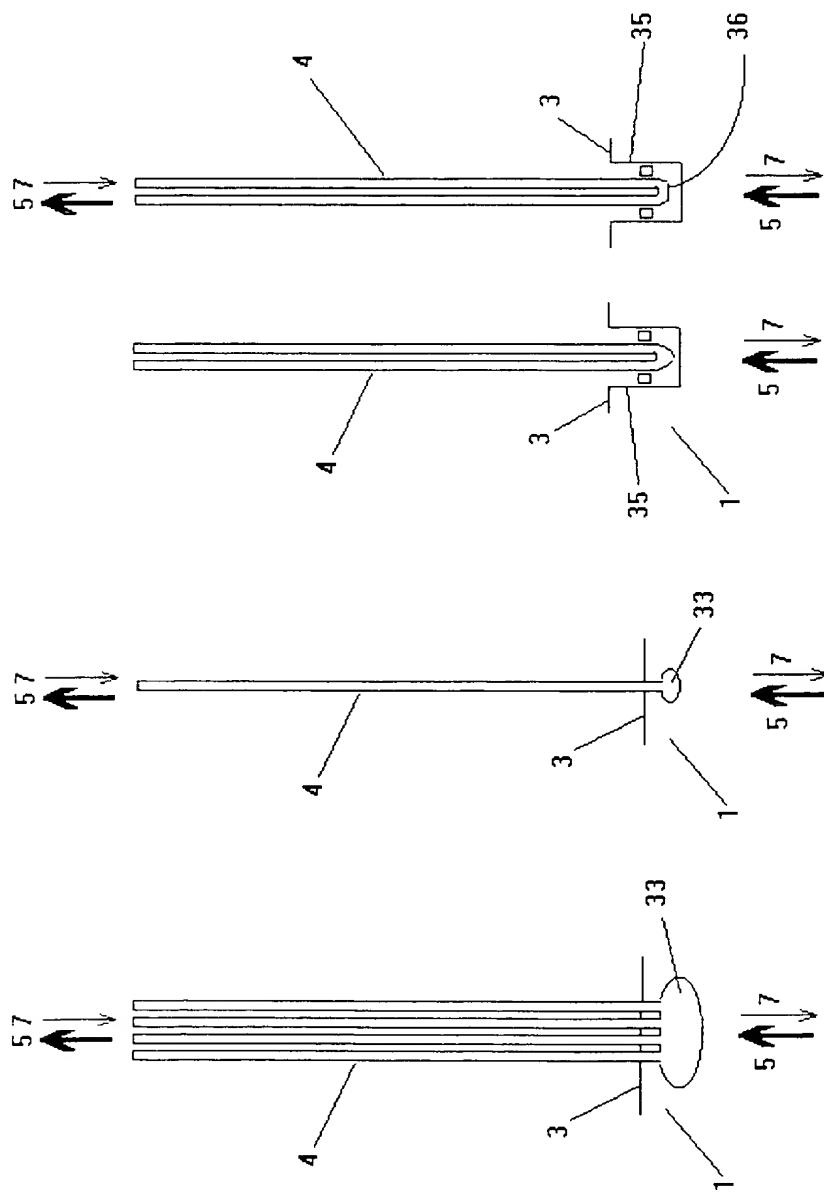


FIG. 11A

FIG. 11B

FIG. 11C FIG. 11D